ANALYSIS AND SUMMARY OF PRESCRIBED FIRE CASE HISTORIES

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- FINAL REPORT -

Analysis and Summary of Prescribed Fire Case Histories

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and the Rocky Mountain Forest and Range Experiment Station

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EXECUTIVE SUMMARY

This report summarizes work completed in fulfillment of cooperative agreement RM-81-190-CA "Analysis and Summary of Prescribed Fire Case Histories," between Colorado State University and the Rocky Mountain Forest and Range Experiment Station. This report synthesizes efforts in the following subject areas: 1) Evaluation of the thoroughness of current prescribed fire reporting practices; 2) Prescribed fire behavior and fire effect modeling potentials; 3) Evaluation of current report formats; and 4) Recommendations for a common report format.

Our summary evaluation of current prescribed fire reporting practices is based on analysis of 412 prescribed fire reports (accompanied by evaluations), submitted in response to our solicitation of 311 field units, staff, and research units of the U.S. Forest Service, National Park Service, Bureau of Land Management, Bureau of Indian Affairs, and selected state agencies. A detailed listing of responses is contained in Appendix A. Report formats vary widely between and within agencies. Reporting thoroughness varies by region, as do the reasons for burning. Hazard reduction is the most-often cited objective for burns, except for the Rocky Mountain region (wildlife habitat improvement). Relatively few reports thoroughly quantify pre- and post-burn measurements necessary to assess objective accomplishment. Also, vague objective statements often preclude assessment of accomplishment. Appendix B summarizes responses to specific key descriptors essential to fire evaluation. Pre-burn measurements are collected more often than post-burn, but both are more often neglected in-evaluations. Less than one-third of all reports included quantitative measurements of fire behavior descriptors, although 90% of the respondents reported prescribed ranges in windspeed and relative humidity.

The potential for fire modeling based on reports received is quite low. We attempted to develop correlations between fire behavior and fire effects, but were hampered by data scarcity and unreliability (Appendix D). The strongest relationship was found between crown scorch height and average flame length (R^2 = .59, n = 17). The data suggest an interesting relationship between control difficulty and perceived degree of success. Apparently, managers prefer fires which burn vigorously and do not require supplementary ignition efforts. Under such circumstances the margin between success and fire escape may be slim. Further, this preference may suggest the need for greater attention and sensitivity to ecological indicators of prescribed fire "success."

Our analysis indicates the need for improvement in current prescribed fire monitoring and evaluation efforts. A standardized intra- and inter-agency report format would enhance prescribed fire practices and facilitate data collection and analysis. We acknowledge the political and operational difficulties associated with implementation, but still believe in the long-term net benefits of standardization. A suggested standardized report format is included (Appendix E) for review and comment.

A manuscript aimed at informing general forestry audiences of the results of our analysis is in preparation.

1. Introduction

Although prescribed fire has gained widespread recognition as a management tool, analytical procedures for planning, executing and evaluating burns have largely been ignored. Such procedures depend on understanding and precise quantification of the various factors affecting fire outcomes, and thus, on thorough prescription fire documentation. Although prescribed fire reports are routinely filled out by all agencies using fire as a management tool, reporting formats and standards are highly variable.

Ideally, all phases of the prescribed burning program should be fully documented in the burning plan, including clear quantifiable statements of burn objectives, desired fire behavior and environmental conditions, and anticipated effects. Monitoring tasks to aid in deciding when to burn and techniques for assessing burn accomplishment should also be outlined. Managers could thus plan future prescribed fires based upon the degree of success or failure of past efforts. In practice, prescription refinement usually results from subjective memory of previous fires and effects rather than recorded evidence of actual conditions that existed before, during, and after each fire. In such situations access to an established data base of previous experiences would provide a valuable information source for improvement of past efforts.

For a variety of reasons, such a data base does not currently exist in an accessible or usable form. Reporting standards tend to vary by agency, region and administrative unit, which makes identification of important information elements difficult. In addition, many managers do not comply with the standards set by their particular agency. For example, pre- and post-burn monitoring tasks specified in the burning plan are often ignored as are real-time fire behavior measurements. As a result,

the task of correlating and communicating results of prescribed fires among fire practitioners is difficult, at best.

If relationships between fire behavior and resultant fire effects are to be established, a thorough post-burn evaluation and description of observed fire behavior are necessary. Furthermore, environmental conditions that precede and occur during the fire must be recorded as well as pre-burn site measurements that relate to stated objectives. Beyond providing a possible means for linking fire behavior to resultant fire effects, quantitative measurements lead to accurate assessment of objective accomplishment and subsequent prescription refinement.

2. Approach

This study was undertaken to evaluate the thoroughness of present prescribed fire reporting practices and to establish any correlations that might exist between reported fire behavior and fire effects. In addition, reporting formats were evaluated in terms of informational content and usefulness for future prescribed fire reporting.

3. Previous Work

The mechanics of writing prescriptions and operational guidelines for execution of successful burning operations have been discussed by several authors, including Beaufait (1962), Riebold (1964), Martin (1978), Martin and Dell (1978), Wright and Bailey (1978), and Fischer (1978). These authors generally contend that prescriptions should specify objectives, desired fire behavior, required environmental conditions, and ignition strategies. Schmidt (1981) states that a prescription should also provide directions for important monitoring tasks to be performed before, during, and after execution.

Typical prescription fire objectives include fuel hazard reduction, range and wildlife habitat improvement, seedbed and site preparation,

increased water yields, and modification of plant species composition. The fire behavior, environmental conditions, and ignition strategies specified within a prescription are a form of control over the types of fires that will achieve the stated objectives. The monitoring tasks conducted before, during, and after execution provide the basis for assessing the extent to which the desired effects have been achieved.

Theoretically, all important information elements in the prescribed fire planning process could be readily identified if literature sources and agency reports fully documented the planning, implementation, and evaluation phases of prescribed fire projects under a standard format. However, the published literature has only recently considered the importance of linking measured fire behavior to fire effects, and is generally inadequate for addressing issues of concern to planners and decision-makers, such as the cost-efficiency of burning or the optimal size of ignition and control forces. At the same time, agency reporting standards tend to vary by agency, region, and administrative unit, and may generally neglect evaluations of ecological significance. Thus there is a need to collect information on historic prescribed fires for purposes of identifying important information elements and to evaluate the utility of various prescribed fire reporting formats. This study focuses mainly on the analysis of agency fire reports, although the existing prescribed fire literature is referenced as necessary.

The analysis of fire reports also provides an opportunity to assess the feasibility of developing simple prediction models of prescribed fire behavior and fire effects. Currently, analytical procedures for planning and executing prescribed burns are hindered by the lack of applicable models relating fire behavior to anticipated environmental conditions, and in turn, the observed fire behavior to resultant fire effects. Rothermel's

(1972) model integrates important fuel, weather, and topographic influences to predict fire spread in uniform, homogeneous fuelbeds. His model has been subsequently used in the estimation of wildfire behavior (summarized in Andrews, 1980) and fire danger (Deeming et al. 1977). Burgan (1979) summarized the differences in assumptions, interpretations, and uses of fire behavior and fire danger prediction based on applications of the Rothermel model to pre-established or 'stylized' fuel models. Albini (1976) concedes the difficulty imposed by the stringent predictive requirements of burning to achieve management objectives, or to reduce the risk of escape or undesirable fire behavior. He suggests that the Rothermel model may be useful in establishing rough estimates for fire behavior that can be combined with experience and careful observation as a prescription fire planning tool.

Several authors have alternatively used statistical regression techniques to develop predictive guidelines for prescribed burning. Lindenmuth and Davis (1973) suggest that statistical models may be more appropriate for specific estimates of fire rate of spread than broad-scale models based on physical principles. Other examples of this approach include Norum's (1974) study relating smoke column height to fire intensity, Miller's (1977) paper on Vaccinium response to differential prescribed fires, and Sandberg's (1980) study of duff reduction in understory burning in Douglas-fir (Pseudotsuga menziesii). The use of regression analysis to develop prediction models from fire report data should be investigated, since little is known about physical principles governing fire behavior - fire effects relationships. Van Wagner and Methven (1978), Rothermel and Deeming (1980), and Dell (1980) suggest the importance of fire intensity as an indicator of fire effects, but much research remains to be done.

Statistical analyses may also be useful for development of site and fire weather-fire behavior relationships in prescribed burning. Factors that contribute to prescription fire success or control difficulty might also be identified and related to the season, time of day, air temperatures, relative humidity, fuel moistures, windspeeds and directions, or other specifications contained in the fire reports. Rothermel and Rinehart (1983) propose a record-keeping procedure that can be used for analysis of fire weather-fire behavior relationships and adjustment of predicted-observed discrepancies in rate of spread and flame length.

To date, no analyses of the informational content of agency prescription fire reports (evaluations) have been attempted. Even if few statistically significant relationships can be developed, such analyses will be useful in the identification of key uncertainties in information, or required improvements in the reporting formats, and planning information needs.

4. Methods

Requests for prescribed fire case histories were sent to 311 field units, staff and research units of the U.S. Forest Service (USFS), National Park Service (NPS), Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), and selected State agencies.[1] We asked that reports be sent to us no later than March 31, 1982. Once the March 31st deadline passed, we telephoned many of the supervisory units from which no reports had been received. This effort was not entirely productive as many managers felt burdened by budgetary and time constraints, and therefore would not contribute reports to the study. However, several of the managers contacted

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[1]See the Study Plan submitted for this project (dated September 17, 1981) for a complete list of agencies contacted.

by phone requested a time extension and submitted their reports during the following month. The units contacted were noted in a letter to the COTR (dated February 26, 1982). Level of response and number of reports received are summarized in Brandel and Omi (1983) and detailed in Appendix A, along with an indication of the number of reports accompanied by a post burn evaluation.

Only those reports that included a post-burn evaluation were subjected to further analysis. Our work would have been simplified if our request for reports had stipulated that only reports with evaluations be submitted. However, we also wished to encourage as large a return as possible; quite possibly, statements restricting the scope of desired responses would have been misinterpreted and discouraged participation.

Reported variables to be included in our analysis (e.g. site descriptors, fire behavior and weather measurements, and pre- and post-burn site measurements) were identified after subsampling submitted reports and noting general response to key descriptors (see Appendix B for summary). As a result of our selecting variables which were common to the majority of reports, not all information was recorded from each report. In all, 177 variables were selected for analysis.

The information contained within each fire report was encoded, to the extent possible, for creation of the data library that was used for analyzing thoroughness of agency reporting practices. Considerable subjective interpretation was needed because much of the report information was either vaguely stated or not included. The format under which information was encoded was noted in the letter to the COTR (dated June 17, 1982) along with the codes used for each of the variables.

The computer program SPSS (Statistical Package for the Social Sciences, Nie _et al_. 1975) was used for the analysis. Standard statistical procedures

were used to analyze frequency distributions, relationships between pre- and post-fire measurements and correlations between measured fire behavior and reported fire effects.

A. Description of Magnetic Tape Library

The data library format and coding conventions are described in the Progress Report dated June 17, 1982. The format and codes were discussed and adopted in a subsequent meeting with the COTR. As agreed at that time, the magnetic tape and computer outputs are being maintained at Colorado State University until such time as requested by the U.S. Forest Service.

5. Results and Discussion

A. Prescribed Fire Evaluations

Four hundred twelve prescribed fire reports accompanied by post-burn evaluations were received and analyzed. An additional 109 reports that lacked post burn evaluations were received but not included in the analysis. The USFS had the largest representation in the 21 states from which reports were received followed by state agencies, NPS and BLM. The BIA did not provide any written reports. Many varied reporting formats were used by and within agencies. For example, eleven different reporting formats were received from the USFS in California. Many reports were written in prose instead of a specified format. In general, we found that standardization in reporting formats within an agency or on a statewide basis is the exception rather than the current rule. Most of the reports addressed the same items, although with varying styles and thoroughness. Many of the reporters, particularly from the USFS, use Martin's (1976) proposed format with minor modifications. The USFS tends to use a more rigid reporting format than does the NPS, whose reports are more frequently written in unstructured prose form.

The proportion of reports specifying particular objectives on a national basis are presented in Table 1. Many of the objectives specified by managers are often vaguely stated and frequently non-quantitative. For example, a typical burn report may specify hazard reduction as the resource objective without indicating how much fuel reduction will satisfy the objective. In general, when the stated objective was not accompanied by a means of assessing objective accomplishment, it was omitted from the

Objective	Percentage Specified
Hazard Reduction	73
Silviculture	11
Site Preparation	28
Wildlife Habitat Improvement	28
Range Management	11
Insect/Disease Control	1
Species Manipulation	14
Aesthetics	8

Table 1: Percentage of reports received specifying particular prescribed fire objectives

	Hazard Reduction	Silvi-culture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Species Manipu-lation	Aesthetics
South	50	7	22	16	7	2	18	7
Pacific Northwest	94	20	62	25	8	3	16	6
East	44	0	25	21	0	0	15	2
Southwest	96	17	6	27	25	0	3	21
Rocky Mountains	37	11	4	74	22	4	44	7
West	87	12	27	29	8	0	2	0
Intermountain	88	3	32	35	18	0	15	9

Table 2: Percentage of reports reviewed by region specifying particular prescribed fire objectives

analysis. However, the report included fire behavior and weather measurements, it was retained for the correlation analysis.

In cases where objectives were not specified, we made inferences where possible based on the available information. Many reports specified multiple objectives. As shown in Table 2, hazard reduction is the foremost reason for burning in all regions except the Rocky Mountains, where wildlife habitat improvement is the primary objective. Insect and disease control is the least often specified reason for burning in all regions. Table 3 notes average and maximum acres burned per fire by region. The Southwest had the largest amount of area accomodated by one burn plan, 8500 acres. Burns that encompassed large amounts of acreage were often conducted during more than one season.

From inspection of Table 4, the neglect of quantitative measurements of site descriptors, fire behavior and environmental indicators becomes apparent. We found that only 30 percent of all respondents measured rate of spread, 28% estimated average flame length and 20% reported maximum flame length. Many of the reports that lacked actual fire behavior measurements were accompanied by pages of TI-59 fire behavior calculations. Actual fire behavior measurements, if made, could be used to improve future TI-59 fire behavior predictions, following procedures outlined by Rothermel and Rinehart (1983).

Weather parameters are consistently reported by prescribed fire practitioners. Actual weather data are more frequently reported than are desired weather parameters. Relative humidity and wind speed are the two most often reported variables, both having at least 90% response. Many of the reports received from the Pacific Northwest did not include a desired temperature range in the prescription. Apparently, many respondents felt temperature differences were embodied in other variables such as

Region	Average Size (Ac)	Maximum Size (Ac)
South	363.5	1671
Pacific Northwest	87.6	2500
East	38.7	273
South West	799.8	8500
Rocky Mountains	217.5	1716
West	136.1	2750
Intermountain	55	258

Table 3: Average and maximum acreage burned per prescribed fire by region

Variables	Percentage
Vegetation	
Overstory Vegetation	74.4
Understory Vegetation	72.9
Fuel Loadings	
Pre-burn 1 hr fuel loading	17.5
Pre-burn 10 hr fuel loading	18.5
Pre-burn 100 hr fuel loading	18.5
Pre-burn 1000 hr fuel loading	15.3
Pre-burn duff depth	16.5
Pre-burn total fuel loading	48.6
Post-burn 1 hr fuel loading	9.0
Post-burn 10 hr fuel loading	9.0
Post-burn 100 hr fuel loading	8.8
Post-burn 1000 hr fuel loading	8.8
Post-burn duff depth	6.5
Post-burn total fuel loading	20.8
Fuel Moistures	
Desired 1 hr fuel moisture	27.0
Desired 10 hr fuel moisture	50.4
Desired 100 hr fuel moisture	11.5
Desired 1000 hr fuel moisture	7.8
Actual 1 hr fuel moisture	32.0
Actual 10 hr fuel moisture	52.1
Actual 100 hr fuel moisture	15.2
Actual 1000 hr fuel moisture	9.5
Weather	
Desired temperature range	61.0
Desired relative humidity range	71.4
Desired wind direction	47.9
Desired wind speed range	72.2
Actual temperature range	86.0
Actual relative humidity range	92.0
Actual wind direction	67.7
Actual wind speed range	90.0
Fire Behavior Indicators	
Ignition pattern	67.2
Type of Burn	42.1
Actual maximum flame length	20.6
Actual average flame length	27.8
Actual rate of spread	29.6
Ignition Component	19.0
Spread Component	10.5
Energy Release Component	16.0
Burning Index	20.8

Table 4: Variables included in fire reports and percentage of respondents reporting measurements on each variable. (from Brandel and Omi, 1983).

relative humidity and fuel moisture. Ironically, some of these same reporters would doubtless be interested in predicting crown scorch height, a fire effect which depends directly on air temperature (Van Wagner, 1973).

Tables 5 through 11 (see Appendix C) show the percentage of respondents from the various regions reporting measurements necessary for assessing objective accomplishment. As shown, a wide range of throughness exists between regions. The eastern region essentially does not record site measurements (Table 9). Although a wider variety of site measurements are made in the Pacific Northwest (Table 11) and the Rocky Mountain States (Table 5), the percentage of respondents quantifying pre- and post-burn site descriptors is typically low, with post-burn measurements averaging less than half of pre-fire measurements. In the Pacific Northwest region, where 94% of all burns are undertaken for hazard reduction, 36% of the respondents measured pre-fire one hour fuel loading, 41% measured both 10- and 100-hour fuel loadings and 28% measured pre-fire 1000 hour fuel loadings. In contrast, post-fire 1 hour, 10 hour, 100 hour, and 1000 hour fuel loadings were measured by 16%, 19%, 18% and 18% of the respondents respectively. Forty-four percent of the eastern respondents specify hazard reduction as their burn objective, however, no quantitative measurements are made that would enable accurate assessment of objective accomplishment.

Table 12 (Appendix D) lists the regression relationships tested in our attempt to establish relationships between fire behavior, fire effects and environmental indicators. The regression models and resultant R^2 values are also shown. We were severely limited in our analysis by the paucity of data and as a result restricted our regression predictors to one independent variable. Due to the relatively low number of cases, the

addition of each independent variable raised the resultant R^2 value, whether or not a relationship existed. For example, 100 hour fuel reduction predicted by energy release component results in an R^2 of .06. By adding average flame length we improved the prediction, raising the R^2 value to .79. Further analysis proved we could also raise the R^2 value by adding a seemingly unrelated variable such as report number to the equation. With that in mind, we limited ourselves to using one independent variable and as a result increased the number of cases for each relationship tested. We feel that stronger relationships between behavior, effects and environmental indicators could be derived if managers were more complete in their reporting practices.

Of all the relationships tested, crown scorch height with average flame length as the predictor appears to be the strongest. We tested both average flame length and flame length squared as predictors. The resultant R^2 values are the same although the model with average flame length squared seems more reasonable, based on inspection of the coefficients.

In addition to a lack of data, we feel that unreliable data contributed to the weakness of relationships developed by regression. For example, two of the cases used for modelling crown scorch reported average crown scorch height of greater than ninety feet. This leads us to wonder if reporters are filling in the blanks on the form just to have a number present.

B. Contingency Analysis

Table 13 shows contingency tables testing the independence of spotting with various environmental indicators. In addition, spotting is tested with assessments of difficulty in controlling the burn. The Chi square values associated with environmental indicators suggest dependencies

between spotting and high maximum windspeeds, low minimum relative humidities, low minimum 1-hour fuel moisture. A weaker association is shown between spotting and maximum temperature. These trends agree with our intuition, ie, spotting should be more likely at high wind speed and low relative humidity. Once again though, we are hampered by the availability of data.

Spotting is more likely to occur when control difficulties are evident on a burn (Table 13). Further, Table 14 indicates that in all cases in which reporters experienced control difficulty on their burns, objective accomplishment was completely met. These findings suggest a rarely reported relationship between control difficulty and objective accomplishment. Apparently burners rarely are able to achieve objectives when sustained ignition cannot be maintained. In this context a fire which is difficult to ignite can be considered as much a 'failure' as one which escapes control, especially since the treatment is not achieved. Further, mobilized and committed resources must be released or remain under-utilized; thus unnecessary treatment costs are incurred.

In addition, from inspection of the contingency tables, there are few reported instances where objectives are not attained. Our inspection finally suggests the possibility that long-term detriments of severe fires may be overlooked in defining prescription fire success.

C. Suggestions Regarding Report Formats

Our analysis indicates current agency reporting practices would be more effective with improved prescribed fire monitoring and evaluation efforts. Our present understanding of fire behavior allows us to measure and, to an extent, predict certain fire characteristics such as rate of spread and flame length. However, we have had limited success in establishing links between fire behavior and fire effects based on submitted reports. Therefore, we must

Table 13:

Spotting	Maximum Wind Speed (mph) 0-4 mph	5-9 mph	10-14 mph	15-19 mph	20-24 mph	25-30 mph
yes	11	21	20	7	4	1
no	17	29	23	8	0	0

Chi square = 6.7 with 5 degrees of freedom Significance = .243
critical value of chi square = 11.07

Spotting	Minimum relative humidity (%) 10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-99%
yes	5	22	18	15	3	1	0	1	1
no	1	17	25	19	6	6	3	0	2

Chi square = 12.75 with 8 degrees of freedom Significance = .12
critical value of chi square = 15.5

Spotting	Minimum 1 hr fuel moisture (%) 0-4%	5-9%	10-14%	15-20%
yes	3	26	9	1
no	1	21	15	0

Chi square = 3.98 with 3 degrees of freedom Significance = .12
critical value of chi square = 15.5

Spotting	Maximum temperature (°F) 20-40	41-60	61-70	71-80	81-90	91-99
yes	0	22	20	12	3	1
no	2	28	25	18	0	1

Chi square = 5.61 with 5 degrees of freedom Significance = .345
critical value of Chi square = 11.07

Spotting	Burnability Hard to Control	Burns without help	Needs help	Won't burn
yes	9	28	2	0
no	1	39	7	2

Chi square = 12.0 with 3 degrees of freedom Significance = .007
critical value of chi square = 7.81

Table 14:

Hazard Reduction Objectives	Burnability: Hard to control	Burns without help[1]	Needs help[2]	Won't burn
completly met	6	53	2	0
> half met	0	9	1	0
not met	0	0	1	2

Chi square = 56.47 with 6 degrees of freedom Significance = .000
critical value of chi square = 12.59

Site Preparation Objectives	Burnability: Hard to control	Burns without help[1]	Needs help[2]
completely met	2	18	0
> half met	0	2	1
not met	0	0	1

Chi square = 15.44 with 4 degrees of freedom Significance = .0039
critical value of chi square = 9.48

Wildlife Habitat Objectives	Burnability: Hard to control	Burns without help[1]	Needs help[2]	Won't burn
completely met	1	12	3	0
> half met	0	2	1	0
not met	0	0	0	1

Chi square = 20.49 with 6 degrees of freedom Significance = .0023
critical value of chi square = 12.59

[1]Additional ignition efforts unnecessary to sustain combustion.

[2]Sustained combustion impossible without additional ignition efforts.

rely upon improved monitoring and evaluation of prescribed fires to gain information about the conditions that will achieve desired fire effects. Although researchers have stressed the merits of monitoring and evaluation programs, managers are often lax in implementing such programs. Prescribed fires are frequently planned and conducted without monitoring of pre-fire, fire and post-fire variables. Thus, subsequent assessment of objective accomplishment is impossible. Information that could be used for refining prescriptions, replicating successful burns, and planning future fires is lost as a result of poor documentation efforts.

Communication of prescribed fire results among managers would be eased if a common approach to monitoring and evaluation was adopted. Currently a variety of prescribed fire monitoring and evaluation programs are endorsed by researchers and various land management agencies. Typically, data collection procedures are not standardized; consequently, comparison of results between burns is difficult. For example, wind speed may be reported as occurring at mid-flame height or at twenty feet. Vegetation may be described in terms of abundance, frequency, or per cent cover. In addition, dates of post-fire evaluations are rarely included in reports. As a result, apparent differences in fire effects between burns may be due to seasonal variation in vegetative response rather than the fire itself.

We feel we have analyzed a representative cross-section of agency prescribed fire reports and reporting standards. Current reporting quality is inadequate in terms of potential uses of information. Although much time has been spent preparing report formats and stipulating what variables to measure, managers repeatedly fail to follow their own guidelines. Time and effort are wasted in making pre-burn site measurements when post-burn measurements are ignored. We found that if pre-burn measurements are recorded, typically less than half the managers follow-up with post-burn

measurements. Actual fire behavior estimates are also frequently ignored. For example, values for rate of spread or flame length on burn reports are typically outputs from TI-59 calculations. TI-59 fire behavior outputs are estimates and, as such, need validation from actual field measurements. As shown by this study, relatively few relationships between fire behavior and fire effects will be established until quantitative measurements are reported.

During our study we looked at report formats in terms of conformance to existing guidelines and utility for future fire planning. Many of the report formats we received are no longer used or have undergone gradual revision. Overall, the informational content of the various formats conforms to existing guidelines, such as Martin and Dell (1978) and Fischer (1978). These guidelines note the importance of documenting environmental prescription elements, site measurements, and actual fire behavior. The reporting format presented by Martin and Dell (Figure 1) has been used extensively (both with and without revisions) throughout the USFS. However, Martin's and Dell's recommendation that a good burn evaluation will require more space than allocated on their form is largely ignored. Therefore, evaluations tend to be scanty as writing space is limited.

The most widespread attempt at standardization in reporting is practiced by the Southwest Interagency Fire Council (SWIFCO). These reports are extremely easy to follow as information is always in the same location. However, statement and evaluation of objectives (Figure 2) are typically reported qualitatively rather than quantitatively. Detailed explanations of burn accomplishment are only required when the objectives are completely not met. In addition, fire behavior predictions and observations (ie. rate of spread, flame length) are not required. The SWIFCO format, at nine pages, is also cumbersome and after a period of time the quantity of paper

Figure 1. Prescribed Burning Plan (Martin and Dell, 1978)

PRESCRIBED BURNING PLAN

FOREST	DISTRICT	FY-
TRI COMPARTMENT (NAME & NUMBER)	GRID NUMBER	BURN UNIT
LOCATION: T _______, R _______, S _______	GROSS AREA	NET AREA
I&E CONTACT	APPROPRIATION(S)	
	EAR PREPARED BY	DATE

BURN AREA DESCRIPTION: DESCRIBE TREES & SHRUBS OVER 12 FEET TALL, SHRUBS & TREES UNDER 12 FEET, AND GRASSES AND FORBS.
ECOCLASS CODE(S)__________ TOPOGRAPHY__________ SLOPE__________ ASPECT__________
SOIL TYPE(S) & DESCRIPTION__________
FUELS (NATURAL &/OR ACTIVITY)
0 -¼" SIZE CLASS __________ T/A SHRUBS __________ T/A TOTAL __________ T/A
¼"-1" SIZE CLASS __________ T/A HERBACEOUS __________ T/A
1"-3" SIZE CLASS __________ T/A DUFF DEPTH __________ IN FUEL CLASSIFICATION __________
3" + SIZE CLASS __________ T/A SURFACE FUEL DEPTH __________ FT NFDR FUEL MODEL __________

MANAGEMENT GOALS OF THIS BURN

OBJECTIVES OF BURN	(CHECK)	(SPECIFICS)
HAZARD REDUCTION	____	__________
SILVICULTURE	____	__________
SITE PREPARATION	____	__________
WILDLIFE HABITAT	____	__________
RANGE MANAGEMENT	____	__________
INSECT/DISEASE CONTROL	____	__________
SPECIES MANIPULATION	____	__________
OTHER	____	__________

BURNING PRESCRIPTION
SEASON__________ TEMPERATURE (RANGE) ____ to ____ °F WIND DIRECTION:
TIME OF DAY__________ RH (RANGE) ____ to ____ % PREFERRED__________
DAYS SINCE RAIN__________ WIND SPEED (RANGE) ____ to ____ MPH ACCEPTABLE__________
FUEL MOISTURES: 1 HR TL ______ %, 10 HR TL ______ %, 100 HR TL ______ %,
1000 HR TL ______ %, DUFF ______ %, SHRUB ______ %, HERBACEOUS ______ %
FLAME LENGTH: MAXIMUM ______, AVERAGE ______ FLAME HEIGHT ______
ALLOWABLE SCORCH HT (FT): CROWN ____, BOLE ____ NFDR DATA: BI ____, ERC ____, IC ____, SC ____
FIRING PATTERN__________ IGNITION METHOD__________

LOGISTICAL INFORMATION
CHAINS LINE TO CONSTRUCT: TRACTOR ____ HAND ____ OTHER (SPECIFY) ____ TOTAL ____
CHAINS LINE TO FIRE: EXTERIOR ____ INTERIOR ____ TOTAL ____
MANPOWER NEEDS: UNIT PREPARATION__________ BURNING__________
HOLDING__________ MOPUP__________
EQUIPMENT NEEDS: UNIT PREPARATION__________
BURNING__________
HOLDING__________
MOPUP__________

BURN SUMMARY
DATE BURNED__________ TIME OF DAY ______ DAYS SINCE RAIN ____ SEAS. PRECIP TO DATE ____ IN.
ACTUAL WEATHER: TEMP ____ RH ____ WIND SPEED & DIRECTION ______ NFDR BI ____
FUEL MOISTURES: 1 HR ____ 10 HR ____ 100 HR ____ 1000 HR ____ BRUSH ____ HERBACEOUS ____
FIRE BEHAVIOR: ROS ______ CH/HR, AVERAGE FLAME LENGTH ______ FT, HEIGHT ______ FT
SCORCH HEIGHT: BOLE ______ FT, CROWN ______ FT
BURN EVALUATION (If additional space is needed, use additional sheet)__________

PLAN PREPARED BY: __________ DATE __________
PLAN REVIEWED BY: __________ DATE __________
PLAN APPROVED BY: __________ DATE __________

NOTE: ATTACH MAP OF BURN AREA

Figure 2. Southwest Interagency Fire Council's Format for Statement of Objectives and Evaluation of Objective Accomplishment

I. MANAGEMENT OBJECTIVES TO BE MET (Be Specific)

Plan Section

1. Lower fuel hazard
2. Create wildlife opening
3. Increase edge effect
4. Provide increase browse for wildlife and livestock
5. Complete FY80 Stinson Burn Plan
6.

Report Section

	Fully Met ( )	Partly Met ( )	Not Met ( )
1.	✓		
2.	✓		
3.	✓		
4.	✓		
5.	✓		
6.			

If objectives were "Not Met," please attach explanation. If burn escaped control, please show escape on map and explain what happened.

accumulated from a large prescribed burning program will be overwhelming.

The burning plan used by the Lolo National Forest (Figure 3) appears to be an expansion of the Martin and Dell form. The drawbacks of this type of form include lack of variables to be monitored for objectives other than hazard reduction and complete lack of post-burn quantitative measurements for assessment of objective accomplishment.

A prescribed fire reporting format must be concise but also allow enough space to report adequate information. Many of the reports we received contained information unnecessary for reporting prescribed fires. For example, the Lolo National Forest form includes treatment alternatives and reasons for their rejection. This seems unnecessary as the decision to use prescribed fire has been made prior to filling out the burning form. If items such as this were eliminated from the report, more space could be allocated to fire effects data.

Many of the reports included fire observation data sheets for recording fire behavior and environmental conditions. An example is shown in Figure 4. Fire behavior and environmental measurements are made at predetermined intervals during the burn and recorded on the form. An additional sheet is required for every monitoring interval. Changes in fire behavior and weather are not easily visualized by this approach since observations may be made ten or more times during a burn, each requiring a separate data sheet. Flipping back and forth between data sheets becomes cumbersome in such instances.

The prescription fire record form developed on the Wallowa-Whitman National Forest (Figure 5) alleviates the problem of visualizing the progression of fire behavior and weather conditions. This form graphically illustrates environmental conditions over twelve time intervals. In addition, fire behavior measurements are presented side by side for the same monitoring periods.

Figure 3. Burning Form (Lolo National Forest)

Lolo Burning Form

ACCOUNTING CODE: ______
TOTAL COST: ______
COST/ACRE: 38.43

FOREST: Lolo DISTRICT: Missoula FY: 80
UNIT: 12A ACRES: 16 COMPARTMENT: 330 SUB COMP: 1 STAND: 09
DRAINAGE: Martin Gulch ELEVATION: TOP 4500 BOTTOM 4100
LOCATION: T 13N R 21W S 14 SLOPE 50-55 % ASPECT E
HABITAT TYPE: DF/Phma EROSION POTENTIAL: Moderate NFDR FUEL MODEL: ______
SOIL TYPE: ______
WATER QUALITY: No year round streams affected
AIR QUALITY: Located west of MSLA. Will be @ optimum ventilation period. Complete mop up will reduce residual smoke duration in the valley.
FUELS: NATURAL ______ ACTIVITY X AGE 2 YRS. ASSESSMENT: L ___ M X H ___
DOWN WOODY PRIVATE PROPERTY ADJACENT: CIC both sides
0-1/4" ______ T/A DUFF DEPTH ______ IN.
1/4-1" ______ T/A TOTAL FUEL ______ T/A
1 - 3" ______ T/A ADJACENT FUEL: ______
3+" ______ T/A

OBJECTIVES OF BURN	(CHECK)	(SPECIFICS)
HAZARD REDUCTION	✓	Reduce to < 20 T/A
SILVICULTURE		
SITE PREPARATION	✓	
WILDLIFE HABITAT	✓	Provide 40-50% mineral soil exposure
RANGE MANAGEMENT		as a minimum.
INSECT/DISEASE CONTROL		Optimize forage production for elk & deer.
SPECIES MANIPULATION		
OTHER		

MANAGEMENT GOALS OF THIS BURN: Optimize forage production for deer & elk. Maintain timber production area which will provide cover area for big game species. Optimize timber growing potential.

TREATMENT ALTERNATIVES (1) Yarding - not selected because of time involved & excessive soil movement (2) Dozer piling - excessive slope & soil disturbance (3) Broadcast Burn - Selected to achieve the management goals in a timely manner and reduce soil damage as much as possible.

BURNING PRESCRIPTION: R.H. 30% ↑-50% Temp. 70-85° TIME OF DAY: Summer 1800-2000 Fall 1500/1400 HRS.
WIND DIRECTION: PREFERRED: SW↓ ACCEPTABLE: S-W SPEED 0 TO 6 MPH
NFDR BI: ______ ALLOWABLE SCORCH HEIGHT: 15- TO 20 FT.
MOISTURE CONTENT: 0-1/4" 8 to 12 % 1-3" 10 to 14 % 3+" ______ to ______ %.
RANGES ACCEPTABLE: DUFF: UPPER 25 TO 75 % LOWER ______ TO ______ % SHRUB 50 TO 150 %
NFDR: ERC ______ TO ______ RATE/SPREAD 2-8 CH/HR FIRELINE: HAND X MECH ______
FIRING PATTERN: Strip head / Backing IGNITION METHOD: Hand drip torch
EXPECTED FIRE BEHAVIOR: Expect a hot backing fire downslope that will consume 80% of < 3" material and up to 50% of fuels > 3".

Add Temp. 70-85° Summer 55°-85° Fall
R.H. 30% ↑ - 50%

PREPARATION: FIRE BOSS: Kevin Brown Assisted by: (1) Wally Bennett and/or (2) Dave Bunnell

MANPOWER NEEDS: BURNING: 4 HOLDING: 20 MOP-UP: 20 Jumpers

HELIPAD: N/A OBSERVERS: -0- RECORDS: 1

EQUIPMENT NEEDS: 4 Tankers w/3 person crews (1000 gal - 600 gal - (2) 200 gal)
4 hand drip torches, 35 tools (Shovels/Pulaskis) 6 Radios Belt weather kit

BURNING: School bus, six pack HOLDING: 4 Saws/fuel MOP-UP: Helicopter bucket

BURNING NARRATIVE: See Attachment.

PREBURN INFORMATION: Taken 3/4/80 Needles 3 Shrubs 173
74-1 13.02

FUEL MOISTURES:

0-1/4"	1-3"	3+"	DUFF: UPPER	LOWER
9.29 %	22.9 %	29.25 %	9.92 %	43.94 %
%	%	%	%	%
%	%	%	%	%
%	%	%	%	%
%	%	%	%	%

WEATHER: (5 DAY PERIOD BEFORE BURN)

DAY	TEMPERATURE	R.H.	WIND SPEED DIRECTION
3/4/80	F°	%	MPH
	F°	%	MPH
	F°	%	MPH
	F°	%	MPH
	F°	%	MPH

BURN EVALUATION: DATE: 8-10-80 TIME OF IGNITION: 1845 STOP 0050

ACTUAL WEATHER:

	TEMPERATURE	L H	R.H.	WIND SPEED	DIRECTION
1 HOUR BEFORE	F°		%	MPH	
START	78 F°	59 - 78	34 %	5 MPH	N/NW
30 MINUTES	64 F°	51 64	43 %	4 MPH	SE
60 MINUTES	66 F°	50 66	37 %	Calm MPH	
	62 F°	48 62	37 %	3 MPH	SE
	F°		%	MPH	

FUEL MOISTURES: 0-1/4" ____ % 1-3" ____ % 3+" ____ % Shrub ____ %

DUFF: UPPER ____ % LOWER ____ %

FIRE BEHAVIOR: RATE/SPREAD ____ CH/HR, ERC ____, $\bar{x}$ FLAME LENGTH ____ FT.

$\bar{x}$ FLAME HEIGHT ____ FT. $\bar{x}$ SCORCH HEIGHT ____ FT.

BURN SUCCESS:

OBJECTIVES MET: YES ✓ NO 90% site Prep was accomplished, Fire was contained fully within the Lines all Hazard eliminated

BURNED WITHIN PRESCRIPTION: YES ✓ NO
Conditions were excellent, well within Prescription

COMMENTS: Recommend this unit be attempted during summer conditions to ensure a better chance of site preparation. DLB

NOTE: Attach photo map.

Figure 4. Fire Observation Data Sheet (Lassen National Forest)

OBSERVER'S NAME SCHRAMEL	DATE 7-1-81
FIRE IDENTIFICATION FISH CREEK	
PLOT # 3	LOCATION
OBSERVATION TIME 2220	FIRE, WIND, SLOPE DIRECTION W
SLOPE	AVERAGE FLAME LENGTH 1'-2'
ASPECT W	MAXIMUM FLAME LENGTH 4' in pockets
SHADE FACTOR —	FLAME HEIGHT 1'
DRY BULB 67	OVERSTORY TORCHING NEG
WET BULB 52	FIREWHIRLS NEG
REL. HUMIDITY 38	SPOTTING OCCURRENCE NEG
LIVE FUEL MOISTURE —	SPOTTING DISTANCE NEG
MIDFLAME WINDSPEED 1	FLAME ZONE WIDTH 5-10
WIND DIRECTION 290°	RATE-OF-SPREAD 1.5 CHS/HR
10 HOUR T.L.	

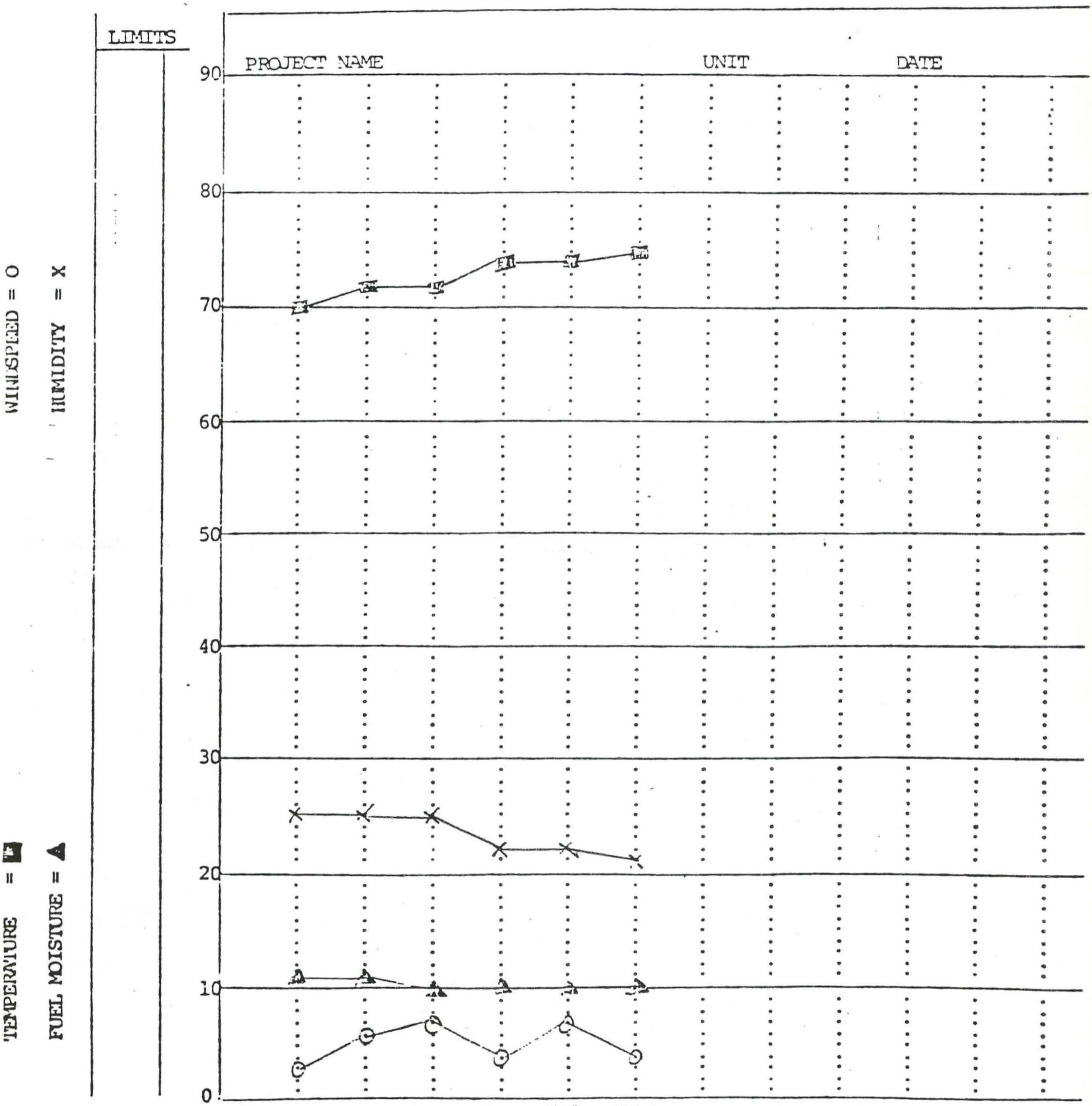
COMMENTS:

DOWN-CANYON WINDS IN EFFECT - CLASSICAL BACKING FIRE AT 2330

2345 - FIRE NOT MOVING AT [illegible] CORNER; DITTO IN OTHER CORNER - FLAME ZONE APPROX. 3'; FLAME HT 1'; MAX. 2'-3'; .

0010 -

Figure 5. Prescription Fire Record Form (Wallowa-Whitman National Forest)



TIME (2400 HR)	1700	1730	[illegible]	1830	1900	1930						
FLAME LENGTH (FT)	1	1	2	2	1	2						
ROS (CH/HR)	1	2	3	2	2	2						
OTHER (WIND DIRECTION)	NW	NW	N	NE	N	NE						

FORM 5150

Changes are, therefore, relatively easy to visualize.

Prescribed fire information sharing is difficult due to the variability in organizational structure of report formats used by public agencies. Typically, unit location and general burn area information are listed first on the form. No generalizations can be made about subsequent items. Objectives, fire behavior, weather information or personnel requirements may follow. Therefore, information retrieval and access by other users, not familiar with a particular format, is difficult.

From our analysis, we have concluded that standardization of reporting formats would enhance agency reporting efforts. However, we realize the impracticality of this suggestion. Monitoring and evaluation programs must be tailored for specific objectives. A standardized reporting format which included variables to be measured for all possible objectives would prove very cumbersome to use. In lieu of strict standardization or reporting formats, we suggest that agencies adhere to an agreed upon organizational structure in their reporting efforts. Within this structure, the monitoring and evaluation section could be modified to suit individual burn objectives. However, although the monitoring and evaluation portion of the report could be changed, variables to be measured for specific objectives would be standardized. Information sharing would be eased as a result of this approach.

Figure 6 (Appendix E) presents a suggested standardized reporting format based upon our analysis of variables currently specified in agency reports, from a review of pertinent literature [Beaufait (1962), Fischer (1978), and Martin and Dell (1978)], and from discussions with experienced fire management and research personnel. Note that this form only considers factors relating to fire behavior and fire effects. To conform to agency standards, personnel and equipment needs, escaped fire contingency, and mop-up needs would have to be added.

We have organized the form into seven sections: 1) Location/Burn Unit Information; 2) Burn Objectives; 3) Monitoring for Fire Effects; 4) Fire Behavior; 5) Environmental Conditions at Time of Ignition; 6) Prescription Fire Record; and 7) Burn Evaluation. Section I, Location/ Burn Unit Information, is self explanatory. Section II, Burn Objectives, is set up so that objectives must be stated in measurable terms. In addition, variables required for assessment of objective accomplishment must be identified. One of the major problems of current reporting practices is the vague statement of objectives. For example, a burn plan may state the resource objective as: Reduction in cover of sagebrush. Although most managers would recognize that removing more than a few sagebrush plants would not meet the intended objective, technically it is all that is required. By stating resource objectives in a quantitative manner, (e.g., % reduction desired), variables to be monitored are also identified and a method for assessing whether resource objectives were met is provided.

Monitoring for Fire Effects, Section III, presents site variables to be measured that relate to specific objectives listed in Section II. Pre- and post-burn measurements are presented side by side for quick comparison. This section could be broken down to include only those variables that relate to the stated objectives.

Section IV, Fire Behavior, is broken into two parts: a) fire behavior as it relates to fire effects inside the burn unit and b) fire behavior as it relates to control outside the unit. Managers are required to report actual fire behavior as well as planned fire behavior. In addition, we have added a column for prescription refinement. We suspect that in the past, managers have rarely used previous reports to help plan for future fires. Prescription parameters that need to be modified are difficult to identify if one or more burning seasons have elapsed since the burn was

conducted. Refinement of the prescription immediately following the burn will preclude guesswork at a later date.

We have broken the fire behavior section into two parts for planning purposes. Part A, Effects, including fire characteristics that relate to objective achievement within the burn unit. Some of these characteristics are observed directly in the field while others are derived from field measurements.

We use NFFL models because they are intended for site specific applications rather than the broad-scale planning efforts best described by NFDRS fuel models. Weather inputs are measured on site and not restricted to fire danger observation procedures. In addition, actual fire characteristics are estimated rather than worst case fire potential.

We have included flame length and rate of spread because they are easy to measure in the field and because other fire characteristics that relate to fire effects can be derived from them. Fireline intensity is directly related to flame length and has been shown to be a predictor of scorch height (Van Wagner, 1973). Heat per unit area is derived from rate of spread and flame length. Fire effects in duff and soil are related to this parameter.

Residence time, the length of time for the fire front to pass a point, is also relatively easy to measure. The rate of spread and flame depth are all that is required. This characteristic may relate to fuel consumption and fire effects in the duff and soil as well as tree mortality due to cambial damage.

The last item included under effects is scorch height, of particular importance in underburn efforts where the objective is not to kill all of the trees on site. Therefore, height of lethal scorch should be reported. Van Wagner's scorch height formula only includes variables that

can be directly measured or derived from field measurements. In addition, Albini (1976) presents graphic aids, derived from Van Wagner's formula, for predicting scorch height. Therefore, practitioners should be able to predict and report this variable with little trouble.

Part B, Control, pertains to control strategies in the event of an escape. Staffing needs for the burn can be based upon the predicted rate of spread and fireline intensity that would result from an ignition outside the unit.

During our study, we encountered many managers who voiced the opinion that fire behavior quantification should be left to researchers. Reasons cited were lack of time, budgetary constraints, and non-relevance of fire behavior quantification to achieving resource targets. Managers should realize, however, that improved evaluations and reporting practices will enhance their predictive capabilities on future prescription fires. Fire behavior quantification, as we have pointed out, does not require much time or effort. However, managers in charge of prescribed burns are often too busy during the burn to take fire measurements. Therefore, someone, other than the burn boss, should be designated and trained as the fire monitor prior to the burn.

Typically, reported heat release values, i.e., fireline intensity and heat per unit area, that appear on fire reports are outputs from TI-59 calculations. We did not encounter one report that used actual measurements of flame length and rate of spread to compute heat release. We suspect that most people who complete burn reports are not aware of the relationships that exist between these variables or else do not know where to reference them. Hence, the opinion persists that fire behavior quantification should be left to researchers.

Section V specifies the environmental conditions at time of ignition.

Generally, reported environmental parameters encompass a wide range to broaden the time periods in which burning can be undertaken. For example, a typical prescription will state that temperature should be within 40° F and 75° F and relative humidity should be between 20% and 40%. A range will also be given for fuel moistures and wind speed. Generally, managers base their prescriptions on these environmental conditions rather than fire behavior characteristics. Problems exist with this approach. A burn may be undertaken at the high or low extremes of any of these environmental parameters and still be considered within prescription. However, with the wrong combination of conditions the fire can either escape control or not burn at all. Ideally, prescriptions should be based upon the desired fire behavior characteristics (ie. flame length, rate of spread, fireline intensity and heat per unit area) that will insure objective attainment. By stating prescriptions in terms of desired fire characteristics we would reduce the chance for an unsuccessful burn due to the wrong combination of environmental conditions.

Presently, our predictive capabilities are restricted to head fires in a limited set of standardized fuel models. These fuel models meet the assumptions of Rothermel's (1972) rate of spread model. Many prescribed fires are conducted in fuels that do not meet the requirements of Rothermel's model. That is, the fuel beds are not continuous or contiguous to the ground. In addition, head fire generally is not the preferred firing pattern on prescribed fires. Therefore, we can not solely rely upon the predictions of fire spread models currently available. We must monitor and document fire behavior and effects on our burns and cross reference them with environmental conditions and ignition techniques utilized during the burn. This course of action would enhance our predictive abilities and enable us to base future prescriptions on fire behavior characteristics

rather than on environmental conditions.

The variables listed in Section V, Environmental Conditions, were chosen on the basis of their contribution to fire behavior or fire effects. Temperature affects relative humidity, fuel moisture, and fuel temperature. However, temperature is not included here for its affect on those variables, but for its relationship to scorch height. Relative humidity is included for its relationship to fuel moisture. Wind speed and direction affect rate of fire spread and intensity. Shading affects fuel temperature and therefore the intensity of the burn. Fuel moistures, duff moisture and soil moistures are all related to fire effects and therefore should be included in a prescription.

Section VI, Prescription Fire Record, allows for graphic documentation of environmental conditions and fire behavior during the course of the burn. Temperature, relative humidity, and wind speed can be measured on site with a belt weather kit while fuel moistures can be monitored with fuel sticks, a portable drying oven/scale combination, or based on TI-59 estimates. The person delegated fire monitoring tasks would be in charge of taking these measurements as well as fire behavior measurements. In addition, space exists on the form for a discretionary measurement such as wind direction, heat per unit area, etc. This record could be supplemented with recording conventions suggested on Rothermel and Rinehart's (1983) suggested format.

Section VII, Burn Evaluation, is an essential part of a prescribed fire program. Monitoring and documentation efforts are wasted if we do not analyze the effectiveness of burn. We should be looking at objective accomplishment, adverse effects on the environment, prescription applicability, and control difficulties. In addition, with the rising concern with budgetary constraints, costs should be listed. Planning preparation,

pre- and post-burn monitoring, firing, holding, mop-up and control, escape, false attempts, and evaluation should all be reflected in the costs. A thorough evaluation will provide justification for the continued existence of a prescribed burning program.

As we have stated before, communication of results from prescribed fires among managers would be eased by use of a standardized reporting format. However, use of a standardized reporting format does not, in itself, solve the problem of access and information retrieval by prescribed fire practitioners. A centralized data storage system accessible to all public agencies appears to be the logical solution. Prescribed fire reports could be archived on floppy discs on in-house computers such as the FLIPS system currently being implemented by the USFS. Information from the disc could then be transferred to a working file at Fort Collins Computer Center (FCCC) when requested by an interested manager. This system would effectively solve two problems. First, on a local level, computerizing prescribed fire reports would enhance access to and organization of the reports. As our prescribed burning efforts increase, so will the reports generated. Keeping track of 10-20 burn reports requires little effort. But over time, we may accumulate ten times that amount. Hand sorting through that much information is extremely time consuming and tedious.

Information sharing among prescribed fire managers is the second problem solved by computerization. Reports could be retrieved according to burn objectives, vegetation type, etc. Access to such a data base would enable managers to benefit from other practitioners' successes and to learn from their failures. In addition, a common data base would enhance our efforts at establishing relationships between fire behavior and fire effects.

Conclusions

Thousands of acres are annually burned by public agencies. However, much of the information from these burns is irrevocably lost to future fire planning and information sharing efforts. We have identified several reasons for this loss. First and foremost, reporting quality is inadequate due to poor monitoring and documentation. Greater attention should be focused on pre- and post-burn site measurements and fire behavior indicators. Our study suggests that most fire managers neglect rudimentary measurements of fire behavior and effects. Thus relatively few relationships between fire behavior, fire effects and environmental conditions could be established from the data collected. Relationships between fire behavior and fire effects can only be substantiated through repeated testing and sharing of quality information by prescribed fire practitioners.

Whether current reporting quality is a result of unfamiliarity with monitoring techniques, simple oversight, or lack of motivation is not apparent from the reports. Whatever the reason, the need for improvement is apparent. Completed reports and evaluations represent a potentially valuable information source that will remain untapped as long as agencies fail to commit the time and effort necessary to share their experiences with others. Practitioners must realize that effective evaluation and documentation will improve their management capabilities. Further, reporting tasks need not and cannot be left to fire scientists. Progress in future prescribed burning efforts will depend on managers who are aware of research questions and capitalize on opportunities for sharing collective experiences.

Future fire planning and information sharing efforts would be enhanced by use of a standardized inter-agency prescribed fire reporting format. In addition, a computerized storage system for the completed reports,

accessible to all agencies would lead to better understanding of important fire behavior/fire effects linkages, facilitate more effective usage of prescribed fire information, and ultimately lead to more efficient overall land management among all fire-using agencies.

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APPENDIX A

Agency and Unit Response to Request for Reports

	Number of Responses	Number of Respondents who use Fire	Number of Reports with Evaluations	Number of Reports without Evaluations
USFS	64	58	323	96
NPS	49	19	37	9
STATE	12	7	49	3
BLM	2	2	3	1
OTHERS	3	2		
TOTAL	130	88	412	109

USFS

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
ALLEGHENY	X	NO		
ANGELES	X	NO		1
APACHE-SITGREAVES	X	YES	6	
ARAPAHOE & ROOSEVELT	X	YES	1	
ASHLEY	X	YES		12
BEAVERHEAD				
BIGHORN	X	YES		1
BITTEROOT				
BLACK HILLS	X	YES	2	
BOISE				
BRIDGER-TETON	X	YES	4	
CARIBOU				
CARSON	X	NO		
CHALLIS				
CHATTAHOOCHEE & OCONEE				
CHEQUAMEGON				
CHEROKEE				
CHIPPEWA				
CHUGACH				
CIBOLA	X	YES	1	
CLEARWATER	X	YES	10	
CLEVELAND				
COCONINO	X	YES	1	
COLVILLE				
CORONADO				
CUSTER	X	YES	3	
DANIEL BOONE				
DEERLODGE				

USFS CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
DESCHUTES	X	YES	10	1
DIXIE				
ELDORADO				
FISHLAKE	X	YES		1
FLATHEAD				
FRANCIS MARION & SUMTER	X	YES	6	
FREMONT	X	YES	7	2
GALLATIN				
GEORGE WASHINGTON	X	YES		1
GIFFORD PINCHOT	X	YES	36	21
GILA	X	YES	15	
GRAND MESA				
GREEN MOUNTAIN				
HELENA	X	YES	1	
HIAWATHA	X	YES	3	
HUMBOLDT				
HURON-MANISTEE				
IDAHO PANHANDLE				
INYO				
JEFFERSON				
KAIBAB				
KISATCHIE	X	YES	4	
KLAMATH	X	YES	13	
KOOTENAI				
LASSEN	X	YES	3	3
LEWIS & CLARK				
LINCOLN	X	YES	1	
LOLO	X	YES	3	

USFS CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
LOS PADRES	X	YES	7	6
MALHEUR				
MANTI-LA SAL	X	YES	2	
MARK TWAIN	X	YES	28	4
MEDICINE BOW				
MENDOCINO				
MODOC	X	YES	12	1
MONONGAHELA	X	YES		2
MT. BAKER-SNOQUALMIE	X	YES	2	
MT. HOOD	X	YES	8	1
NATIONAL FORESTS IN ALABAMA	X	YES	4	
NATIONAL FORESTS IN FLORIDA				
NATIONAL FORESTS IN MISSISSIPPI	X	YES	18	24
NATIONAL FORESTS IN NORTH CAROLINA				
NATIONAL FORESTS IN TEXAS	X	YES	12	
NEBRASKA	X	YES	2	1
NEZPERCE	X	YES	3	
NICOLET				
OCHOCO	X	YES	3	
OKANAGAN	X	YES	3	
OLYMPIC				
OTTAWA				
OUACHITO				
OZARK & ST. FRANCIS				
PAYETTE				
PIKE & SAN ISABEL	X	YES	2	1

USFS CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
PLUMAS	X	YES	5	
PRESCOTT	X	YES	10	
RIO GRANDE				
ROGUE RIVER	X	YES	1	
ROUTT	X	YES	1	
SALMON	X	YES	8	
SAN BERNADINO				
SAN JUAN	X	YES	5	
SANTA FE	X	YES	1	1
SAWTOOTH				
SEQUOIA	X	NO		
SHASTA-TRINITY				
SHAWNEE				
SHOSHONE	X	YES	2	
SIERRA	X	YES	1	5
SISKIYOU	X	YES	4	
SIUSLAW				
SIX RIVERS				
STANISLAUS	X	NO		
SUPERIOR				
SWIFCO	X	YES	26	4
TAHOE	X	YES	1	
TARGHEE	X	YES	4	
TOIYABE				
TONGASS-CHATHAM AREA				
TONGASS-KETCHICAN AREA	X	NO		

USFS CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
TONGASS-STIKINE				
TONTO	X	YES	3	
UINTA				
UMATILLA				
UMPQUA				
WALLOWA-WHITMAN	X	YES	4	
WASATCH				
WAYNE-HOOSIER				
WENATCHEE	X	YES	3	1
WHITE MOUNTAIN	X	YES	1	
WHITE RIVER	X	YES	5	
WILLAMETTE	X	YES	2	2
WINEMA				
OTAL 121	64	58 YES	323	96

NPS

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
ACADIA NP	X	NO		
ALLEGHENY PORTAGE RAILROAD NHS				
AMISTAD NRA				
BADLANDS NP				
BANDELIER NM	X	YES	2	
BIG BEND NP	X	YES	1	
BIG CYPRESS NATIONAL PRESERVE				
BIG HORN CANYON NRA				
BIG SOUTH FORK NATL. RIVER AND REC. AREA				
BIG THICKET NATL. PRESERVE	X	YES	3	2
BRYCE CANYON NP	X	NO		
BUFFALO NATIONAL RIVER	X	NO		
CAPE COD NS	X	YES	1	
CAPE HATTERAS NS				
CAPE LOOKOUT NS	X	NO		
CAPITAL REEF NP				
CHACO CANYON NM	X	NO		
CHANNEL ISLANDS NM	X	NO		
CHATTAHOOCHEE RIVER NRA				
CHICKAMAUGA & CHATTANOOGA NMP				
COLONIAL NHP	X	NO		
CONGAREE SWAMP NM	X	NO		
CRATER LAKE NP	X	YES	3	
CRATERS OF THE MOON NM				
CUMBERLAND GAP NHP				
DELAWARE WATER GAP NRA				

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
DEVILS TOWER NM				
DINOSAUR NM	X	YES		1
EVERGLADES	X	YES		
FORT DONELSON NMP				
FREDERICKSBURG & SPOTSYLVANIA NMP	X	NO		
GATEWAY NRA	X	YES	1	
GETTYSBURG NMP				
GLACIER NP	X	NO		
GOLDEN GATE NRA				
GOLDEN SPIKE NHS				
GRAND CANYON NP				
GRAND TETON NP	X	YES	1	
GRANT-KOHRS RANCH NHS	X	NO		
GREAT SMOKEY MTS. NP	X	NO		
GUADALUPE MTS. NP & CARLSBAD CAVERNS	X	YES	2	
GUILFORD COURTHOUSE NMP	X	NO		
GULF ISLANDS NS				
HALEAKALA NP				
HARPERS FERRY NHP	X	NO		
HOT SPRINGS NP				
ISLE ROYALE NP	X	NO		
JEAN LAFITTE NHP & PRESERVE	X	NO		
JEWELL CAVE NM				
JOSHUA TREE NM				
KINGS MOUNTAIN NMP	X	NO		
LAKE CHELAN NRA	X	NO		
LAKE MEAD NRA	X	NO		

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
LASSEN VOLCANIC NP				
LAKE MEREDITH NRA	X	YES	3	
MANASSAS NATL. BATTLEFIELD PARK				
MESA VERDE NP				
MOORES CREEK NMP	X	YES		1
MT. RAINIER NP				
MOUNT RUSHMORE NM	X	NO		
MUIR WOODS NM				
NORTH CASCADES NP	X	NO		
OCMULGEE NM				
OLYMPIC NP	X	NO		
PADRE ISLAND NS	X	NO		
PEA RIDGE NMP	X	NO		
PETERSBURG NATL. BATTLEFIELD	X	NO		
PINELANDS NR				
PINNACLES NM	X	YES		1
POINT REYES NS	X	YES		
PRINCE WILLIAM FOREST PARK				
REDWOOD NP				
ROCKY MOUNTAIN NP	X	YES		
ROOSEVELT VANDERBILT NHS	X	NO		
ROSS LAKE NRA	X	NO		
SANTA MONICA MOUNTAINS NP				
SARATOGA NHP	X	NO		
SEQUOIA-KINGS CANYON NP	X	YES	3	
SHENANDOAH NP	X	YES	8	
SHILOH NMP				
STONES RIVER NATL. BATTLEFIELD				

NPS CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
THEODORE ROOSEVELT NP				
VALLEY FORGE NHP				
VICKSBURG NMP				
WASHINGTON MEMORIAL PARKWAY				
WHISKEYTOWN-SHASTA-TRINITY NRA				
WIND CAVE NP	X	YES	9	4
YELLOWSTONE NP	X	NO		
YOSEMITE NP	X	YES, but won't participate		
ZION NP	X	NO		
TOTAL 90	49	19 YES	37	9

BLM

		RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
	ALASKA				
	ARIZONA	X	YES		1
	CALIFORNIA				
	COLORADO	X	YES	3	
	IDAHO				
	MONTANA				
	NEVADA				
	NEW MEXICO				
	OREGON				
	UTAH				
	WYOMING				
TOTAL	11	2	2 YES	3	1

STATE	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
ALABAMA				
ALASKA				
ARIZONA				
ARKANSAS				
CALIFORNIA				
COLORADO				
FLORIDA	X	NO		
GEORGIA				
HAWAII				
IDAHO				
KANSAS	X	YES		
KENTUCKY	X	NO		
LOUISIANA	X	YES		
MARYLAND	X	YES	3	
MICHIGAN				
MINNISOTA				
MISSISSIPPI				
MISSOURI				
MONTANA				
NEBRASKA	X	YES	1	
NEVADA	X	NO		
NEW JERSEY				
NEW MEXICO				
NORTH CAROLINA	X	YES	34	
NORTH DAKOTA	X	NO		
OREGON	X	NO		
SOUTH CAROLINA				
SOUTH DAKOTA				

STATE CONT.

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
TENNESSEE				
TEXAS				
UTAH				
VIRGINIA				
WASHINGTON				
WEST VIRGINIA				
WISCONSIN	X	YES	11	2
WYOMING	X	YES		1
TOTAL 36	12	7 YES	49	3

OTHERS

	RESPONSE	PRESCRIBED FIRES	REPORTS WITH EVALUATIONS	REPORTS WITHOUT EVALUATIONS
JIM AGEE				
DAVID BUTTS				
KATHLEEN DAVIS				
JACK DIETERICH	X	YES		
LISLE GREEN	X	YES		
CHARLIE HARDEN				
W. R. HARMS				
BRUCE KILGORE				
JAMES LOTAN				
DAVID MCNABB	X	NO		
ROBERT MARTIN				
LEE NEUENSHWANDER				
LEN NEWELL				
HENRY A. PEARSON				
ROD NORUM				
DAVE PETERSON				
STEWART PICKFORD				
KLAUS RADTKE				
GEORGE ROBY				
DAVID SANDBERG				
GORDIE SCHMIDT				
CHARLES TANDY - BIA				
JACK TROYER				
RON WAKIMOTA				
JACK WILSON				
HENRY WRIGHT	X	YES	CONSULT "FIRE ECOLOGY"	
TOTAL 26	3	2 YES		

APPENDIX B

Response of Reporters to Specific Key Descriptors Identified on Fire Evaluation Coding Form

Variable	Percentage Reporting
State of origin	100.0
Agency	100.0
Size in acres	90.0
Overstory vegetation	74.4
Understory vegetation	73.7
Slope minimum	58.6
Slope maximum	58.6
Topography	5.0
Soil type	7.8
Aspect	55.6
Elevation	40.4
Position on slope	20.8
Type of burn	42.4
Hazard reduction objective	72.4
Silviculture objective	11.8
Site preparation objective	27.3
Wildlife habitat improvement objective	27.6
Range management objective	11.5
Insect/disease control objective	1.8
Species manipulation objective	13.8
Aesthetics objective	8.5
Degree hazard reduction objectives met	70.4
Degree silvicultural objectives met	11.0
Degree site prep objectives met	25.3
Degree wildlife habitat objectives met	24.3
Degree range management objectives met	11.0
Degree insect/disease control objectives met	.5
Degree species manipulation objectives met	13.5
Degree aesthetics objectives met	8.0
Pre-burn 1 hour fuels (tons/acre)	17.5
Pre-burn 10 hour fuels (tons/acre)	18.5
Pre-burn 100 hour fuels (tons/acre)	18.5
Pre-burn 1000 hour fuels (tons/acre)	15.3
Pre-burn shrubs (tons/acre)	5.0
Pre-burn herbaceous (tons/acre)	2.3
Pre-burn duff depth (inches)	16.5
Pre-burn fuel depth (feet)	18.5
Pre-burn fuels (tons/acre)	48.6
Pre-burn mineral soil exposure	1.8
Pre-burn percent shrub crown cover	.5
Pre-burn plants/acre	.5
Pre-burn percent dead	16.5
Desired reduction in 1 hour fuels	27.3
Desired reduction in 10 hour fuels	25.6
Desired reduction in 100 hour fuels	22.3
Desired reduction in 1000 fuels	15.0
Desired reduction in shrubs	5.0
Desired reduction in herbaceous	1.8
Desired reduction in duff depth	3.8
Desired reduction in fuel depth	1.3
Desired reduction in fuel loading	13.5

Variable	Percentage Reporting
Desired increase in mineral soil exposure	13.8
Desired reduction in shrub crown cover	1.0
Desired reduction in plants/acre	3.5
Desired reduction in dead fuels	.3
Post-burn 1 hour fuels (tons/acre)	9.0
Post-burn 10 hour fuels (tons/acre)	9.0
Post-burn 100 hour fuels (tons/acre)	8.8
Post-burn 1000 hour fuels (tons/acre)	8.8
Post-burn shrubs (tons/acre)	.3
Post-burn herbaceous (tons/acre)	.8
Post-burn duff depth (inches)	6.5
Post-burn fuel depth (feet)	4.3
Post-burn total fuel (tons/acre)	20.8
Post-burn mineral soil exposure (percent)	1.8
Post-burn shrub crown cover (percent)	.5
Post-burn plants/acre	.5
Post-burn percent dead	
Age of slash (years)	29.1
Arrangement of fuels	30.1
Tree damage	17.8
Soil Movement or other adverse effects	10.5
Pre-burn treatment	16.5
Desired season	41.6
Desired temperature minimum	60.9
Desired temperature maximum	61.2
Desired time of day	20.3
Desired RH minimum	71.7
Desired RH maximum	71.4
Desired days since rain	18.3
Desired amount of rain	4.8
Desired wind direction	47.9
Desired wind speed minimum	72.2
Desired wind speed maximum	72.2
Desired cloud cover	3.3
Actual season	84.7
Actual temperature minimum	86.2
Actual temperature maximum	86.0
Actual time of day	52.4
Actual RH minimum	91.7
Actual RH maximum	92.0
Actual days since rain	24.8
Actual amount of rain	9.3
Actual wind direction	67.7
Actual wind speed minimum	90.0
Actual wind speed maximum	90.2
Actual cloud cover	16.0
Desired 1 hr tl fuel moisture minimum	26.3
Desired 1 hr tl fuel moisture maximum	27.3
Desired 10 hr tl fuel moisture minimum	50.6
Desired 10 hr tl fuel moisture maximum	50.4

Variable	Percentage Reporting
Desired 100 hr tl fuel moisture minimum	11.5
Desired 100 hr tl fuel moisture maximum	11.3
Desired 1000 hr tl fuel moisture	7.8
Actual 1 hr tl fuel moisture minimum	31.3
Actual 1 hr tl fuel moisture maximum	32.1
Actual 10 hr tl fuel moisture minimum	52.1
Actual 10 hr tl fuel moisture maximum	52.1
Actual 100 hr tl fuel moisture minimim	15.5
Actual 100 hr tl fuel moisture maximum	14.8
Actual 1000 hr tl fuel moisture	9.5
Desired upper duff moisture	3.8
Desired lower duff moisture	2.5
Desired shrub moisture	6.0
Desired herbaceous moisture	5.5
Desired soil moisture	6.8
Actual upper duff moisture	1.5
Actual lower duff moisture	1.8
Actual shrub moisture	10.5
Actual herbaceous moisture	4.0
Actual soil moisture	5.8
Desired maximum flame length	18.5
Desired average flame length	17.0
Desired flame height	7.3
Desired crown scorch height	1.8
Desired bole scorch height	6.5
Desired rate of spread (chains/hr)	19.8
Firing pattern	67.2
Ignition method	46.6
Actual maximum flame length	20.6
Actual average flame length	27.8
Actual flame height	11.5
Actual crown scorch height	6.0
Actual bole scorch height	18.5
Actual rate of spread (chains/hr)	29.6
Smoke management	7.0
Desired column height	7.5
Desired direction of drift	8.8
Actual column height	14.3
Actual direction of drift	8.8
Desired ignition component	13.3
Desired spread component	5.0
Desired energy release component	9.0
Desired burning index	17.5
Actual ignition component	19.0
Actual spread component	10.5
Actual energy release component	16.0
Actual burning index	20.8
Burnability	25.8
Spotting occurence	38.1
Severity of burn	14.0

Variable	Percentage Reporting
Acreage burned outside pre-planned area	16.3
Torched trees	6.0
Number of personnel	59.4
Number of tankers	41.1
Number of tractors	13.0
Line width (feet)	8.0
Amount of line (chains)	14.5
Type of line	30.1

APPENDIX C

Summary of Measurements Related to Objective Accomplishment, by Region

	Hazard Reduction	Silvi-culture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Species Manipu-lation	Aesthetics
Prefire 1 hr fuel loading	40	66	100	40	50	100	17	100
Pre-fire 10 hr fuel loading	40	66	100	40	50	100	17	100
Pre-fire 100 hr fuel loading	40	66	100	40	50	100	17	100
Pre-fire 1000 hr fuel loading	40	66	100	10	17	100		50
Pre-fire shrub loading				15				
Pre-fire herbaceous loading	10			10				
Pre-fire duff depth	40	66	100	25	50	100	17	100
Pre-fire fuel depth	50	66	100	20	33	100	8	50
Pre-fire total fuel loading	60	66	100	50	50	100	17	100
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading	40	66	100	10	17	100		50
Post-fire 10 hr fuel loading	40	66	100	10	17	100		50
Post-fire 100 hr fuel loading	40	66	100	10	17	100		50
Post-fire 1000 hr fuel loading	40	66	100	10	17	100		50
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth	10							
Post-fire fuel depth	10							
Post-fire total fuel loading	50	66	100	15	17	100		50
Post-fire soil exposure								
Post-fire shrub cover								
Upper duff moisture								
Lower duff moisture								
Shrub moisture								
Herbaceous Moisture								
Soil Moisture								

Table 5: Percentage of respondents from Rocky Mountain Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silviculture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Speci Manipulation	Aesthetics
Prefire 1 hr fuel loading	24		39	21			100	
Pre-fire 10 hr fuel loading	26	17	39	29			100	
Pre-fire 100 hr fuel loading	26	17	39	29			100	
Pre-fire 1000 hr fuel loading	29	17	46	36			100	
Pre-fire shrub loading	5	15						
Pre-fire herbaceous loading	5	15						
Pre-fire duff depth	12	17	15	14	25			
Pre-fire fuel depth	19	17	31	14	25		100	
Pre-fire total fuel loading	67	67	69	64	25		100	
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading	19		31	21			100	
Post-fire 10 hr fuel loading	19		31	21			100	
Post-fire 100 hr fuel loading	19		31	21			100	
Post-fire 1000 hr fuel loading	19		31	21			100	
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth	5			7				
Post-fire fuel depth								
Post-fire total fuel loading	26		39	29			100	
Post-fire soil exposure								
Post-fire shrub cover								
Upper duff moisture								
Lower duff moisture								
Shrub moisture	38	50	54	43	50			
Herbaceous Moisture	12		23	7				
Soil Moisture								

Table 6: Percentage of respondents from Western Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silvi-culture	Site Preparation	Habitat Improvement	Range Management	Insect and Disease Control	Species Manipulation	Aesthetics
Prefire 1 hr fuel loading	4	16					6	
Pre-fire 10 hr fuel loading								
Pre-fire 100 hr fuel loading								
Pre-fire 1000 hr fuel loading								
Pre-fire shrub loading								
Pre-fire herbaceous loading								
Pre-fire duff depth	8		5	6				
Pre-fire fuel depth	34	16	50	46	16		17	14
Pre-fire total fuel loading	56	66	95	40	16		23	43
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading								
Post-fire 10 hr fuel loading								
Post-fire 100 hr fuel loading								
Post-fire 1000 hr fuel loading								
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth								
Post-fire fuel depth								
Post-fire total fuel loading	19		75	13	16			
Post-fire soil exposure								
Post-fire shrub cover								
Upper duff moisture								
Lower duff moisture								
Shrub moisture	19			13	16		12	
Herbaceous Moisture								
Soil Moisture	4							14

Table 7: Percentage of respondents from Southern Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silvi-culture	Site Preparation	Habitat Improvement	Range Management	and Disease Control	Manipu-lation	Aesthetics
Prefire 1 hr fuel loading	10	8	25					
Pre-fire 10 hr fuel loading	3		25					
Pre-fire 100 hr fuel loading	2		25					
Pre-fire 1000 hr fuel loading	3		25					
Pre-fire shrub loading								
Pre-fire herbaceous loading								
Pre-fire duff depth	2				6			
Pre-fire fuel depth								
Pre-fire total fuel loading	28	42	25	11	33		50	20
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading	3		25					
Post-fire 10 hr fuel loading	2		25					
Post-fire 100 hr fuel loading								
Post-fire 1000 hr fuel loading								
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth								
Post-fire fuel depth								
Post-fire total fuel loading	18	17	25	5	22			
Post-fire soil exposure								
Post-fire shrub cover								
Upper duff moisture								
Lower duff moisture								
Shrub moisture	3			5			7	
Herbaceous Moisture								
Soil Moisture								

Table 8: Percentage of respondents from Southwest Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silvi-culture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Species Manipu-lation	Aesthetics
Prefire 1 hr fuel loading								
Pre-fire 10 hr fuel loading								
Pre-fire 100 hr fuel loading								
Pre-fire 1000 hr fuel loading								
Pre-fire shrub loading				10			14	
Pre-fire herbaceous loading								
Pre-fire duff depth								
Pre-fire fuel depth								
Pre-fire total fuel loading								
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading								
Post-fire 10 hr fuel loading								
Post-fire 100 hr fuel loading								
Post-fire 1000 hr fuel loading								
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth								
Post-fire fuel depth								
Post-fire total fuel loading								
Post-fire soil exposure								
Post-fire shrub cover								
Upper duff moisture								
Lower duff moisture								
Shrub moisture								
Herbaceous Moisture								
Soil Moisture								

Table 9: Percentage of respondents from Eastern Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silvi-culture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Species Manipu-lation	Aesthetics
Prefire 1 hr fuel loading	47	100	36	17			20	67
Pre-fire 10 hr fuel loading	70		73	42	50		80	67
Pre-fire 100 hr fuel loading	74	100	82	42	50		80	67
Pre-fire 1000 hr fuel loading	74	100	82	42	50		80	67
Pre-fire shrub loading								
Pre-fire herbaceous loading								
Pre-fire duff depth	60	100	36	42	50		80	67
Pre-fire fuel depth	37	100		8				33
Pre-fire total fuel loading	84	100	91	42	50		80	67
Pre-fire soil exposure								
Pre-fire shrub cover								
Post-fire 1 hr fuel loading	33		18	17				67
Post-fire 10 hr fuel loading	30		18	17				67
Post-fire 100 hr fuel loading	33		18	17				67
Post-fire 1000 hr fuel loading	33		18	17				67
Post-fire shrub loading								
Post-fire herbaceous loading								
Post-fire duff depth	37		9	8				33
Post-fire fuel depth	33							
Post-fire total fuel loading	50		46	17				67
Post-fire soil exposure	7		18		8			33
Post-fire shrub cover								
Upper duff moisture	7		18	8				33
Lower duff moisture	17		18	8				33
Shrub moisture	10		18	25				
Herbaceous Moisture	7		18					
Soil Moisture								

Table 10: Percentage of respondents from Intermountain Region reporting measurements necessary for assessing accomplishment of indicated objective.

	Hazard Reduction	Silvi-culture	Site Preparation	Wildlife Habitat Improvement	Range Management	Insect and Disease Control	Species Manipu-lation	Aesthetics
Prefire 1 hr fuel loading	36	88	20	80	67	50	92	
Pre-fire 10 hr fuel loading	41	94	22	85	67	50	92	20
Pre-fire 100 hr fuel loading	41	94	22	85	67	50	92	20
Pre-fire 1000 hr fuel loading	28	31	25	35	67	50	15	20
Pre-fire shrub loading	19	75	4	65	17		92	
Pre-fire herbaceous loading	7	13	2	10	33		8	
Pre-fire duff depth	38	94	18	85	50		92	20
Pre-fire fuel depth	18	19	16	25	33		15	
Pre-fire total fuel loading	73	88	74	80	50	50	92	60
Pre-fire soil exposure	8	6	2	5	33			
Pre-fire shrub cover	3				17			
Post-fire 1 hr fuel loading	16	19	10	20	50		8	
Post-fire 10 hr fuel loading	19	25	10	25	50		15	
Post-fire 100 hr fuel loading	18	19	10	20	33		15	
Post-fire 1000 hr fuel loading	18	19	10	20	33		15	
Post-fire shrub loading	1		2	5			8	
Post-fire herbaceous loading	4	6		5	17		8	
Post-fire duff depth	16	25	10	25	17		15	20
Post-fire fuel depth	8	13	6	15	17		8	
Post-fire total fuel loading	21	19	16	15	17		8	
Post-fire soil exposure	5	6		5	33			
Post-fire shrub cover	3				17			
Upper duff moisture	4		2		17			
Lower duff moisture	3				17			
Shrub moisture	1		2					
Herbaceous Moisture	5		4		17			
Soil Moisture	24		39	5	17			40

Table 11. Percentage of respondents from Pacific Northwest Region reporting measurements necessary for assessing accomplishment of indicated objective.

APPENDIX D

List of Regression Relationships Tested

Table 12: Regression relationships tested between dependent and independent variables

Dependent Variable	Independent Variable	n	R^2	Equation
Crown scorch (ft)	Average flame length (ft)	17	.58	SCORCHHT = 6.03 AVEFL - 4.63
Crown scorch (ft)	Average flame length (ft^2)	17	.59	SCORCHHT = .481 AVEFLSQ + 6.99
Crown scorch (ft)	Average flame length (ft)	16	.59	SCORCHHT = 5.94 AVEFL + .309 TEMP - 22.74
	Maximum temperature (F°)			
Crown scorch (ft)	Average flame length (ft)	17	.61	SCORCHHT = 5.61 AVEFL - 3.88 AVEWIND + 12.6
	Average wind speed (mph)			
1 hr fuel reduction (%)	Average flame length (ft)	24	.08	PCENT1 = .714 AVELF - .014 RH + 82.9
	Minimum relative humidity (%)			
1 hr fuel reduction (%)	Minimum relative humidity (%)	10	.31	PCENT L = .752 RH + 1.87 ROS - .975 AVEFL + 50.45
	Rate of spread (ch/hr)			
	Average flame length (ft)			
1 hr fuel reduction (%)	Average 10 hr fuel moisture (%)	10	.04	PCENT1 = -.465 AVE10FM + .414 AVEFL + 92.61
	Average flame length (ft)			
10 hr fuel reduction (%)	Average 10 hr fuel moisture (%)	8	.66	PCENT10 = -8.17 AVE10FM + .508 ROS + 1.46 AVEFL + 157.42
	Rate of spread (ch/hr)			
	Average flame length (ft)			
10 hr fuel reduction (%)	Average 10 hr fuel moisture (%)	19	.07	PCENT10 = .264 AVE10FM + 1.15 AVEFL + 67.82
	Average flame length (ft)			
100 hr fuel reduction (%)	Energy Release Component (NFDRS)	9	.06	PCENTHU = .374 ERC + 52.84
100 hr fuel reduction (%)	Energy Release Component (NFDRS)	9	.91	PCENTHU = .051 ERC + 2.79 REPORTNO + 9.32
	Report number			

100 fuel reduction (%)	Energy Release Component (NFDRS) Wind direction	6	.41	PCENTHU = .687 ERC - 2.43 WINDIREC + 61.72
100 hr fuel reduction (%)	Energy Release Component (NFDRS) Area burned (ac)	9	.82	PCENTHU = .715 ERC - .172 ACRES + 50.57
100 hr fuel reduction (%)	Energy Release Component (NFDRS) Average flame length (ft)	7	.79	PCENTHU = -.377 ERC + 11.20 AVEFL + 35.92
100 hr fuel reduction (%)	Average flame length (ft) Average 10 hr fuel moisture (%)	19	.09	PCENTHU = 1.94 AVEFL - .161 AVE10FM + 56.83
1000 hr fuel reduction (%)	Average flame length (ft) Average 10 hr fuel moisture (%)	19	.30	PCENTTH = .936 AVEFL - 5.87 AVE10FM + 112.78
1000 hr fuel reduction (%)	Average flame length (ft) Energy release component (NFDRS)	7	.50	PCENTTH = -13.19 AVEFL + 1.71 ERC + 19.67
1000 hr fuel reduction (%)	Energy release component (NFDRS)	9	.08	PCENTTH = .743 ERC + 11.27
Average flame length (ft)	Average slope (%)	65	.14	AVEFL = .156 AVESLOP + 2.22
Average flame length (ft)	Rate of spread (ch/hr)	63	.02	AVEFL = .053 ROS + 4.44
Average flame length (f)	Average wind speed (mph)	105	.00	AVEFL = -.049 AVEWIND + 5.61
Average flame length (ft)	Average wind speed (mph) Average slope (%)	61	.18	AVEFL = .486 AVEWIND + .188 AVESLOP - .690
Average flame length (ft)	Average slope (%) Rate of spread (ch/hr) Average 1 hr fuel moisture (%) Average wind speed (mph)	15	.80	AVEFL = .206 AVESLOP - .030 ROS - .037 AVE1fM + .880 AVEWIND - 3.76

Average flame length (ft)	Average slope (%)	65	.14	AVEFL = .156 AVESLOP + 2.22
	1 hr fuel loading (T/A)			
	Maximum slope (%)			
Average flame length (ft)	Rate of spread (ch/hr)	33	.17	AVEFL = .029 ROS + 1.53 AVESLOP + .341 AVEWIND + .497
	Average slope (%)			
	Average wind speed (mph)			
Average flame length (ft)	Minimum wind speed (mph)	61	.24	AVEFL = .609 MINWIND - .008 MAXSLOP + .214 MAXWIND + .219 MINSLOP - .989
	Maximum slope (%)			
	Maximum wind speed (mph)			
	Minimum slope (%)			
Rate of spread (ch/hr)	Minimum 1 hr fuel moisture (%)	23	.41	ROS = -.756 FM1HR + .479 SLOPE + 4.69 WINDSPD - 21.97
	Maximum slope (%)			
	Maximum wind speed (mph)			
Rate of spread (ch/hr)	Average 1 hr fuel moisture (%)	22	.18	ROS = .157 AVE1FM + .241 AVESLOP + 4.21 AVEWIND - 11.69
	Average slope (%)			
	Average wind speed (mph)			
Rate of spread (ch/hr)	Minimum 1 hr fuel moisture (%)	22	.68	ROS = .504 MINFM - .819 MINSLOP + 6.26 MAXWIND -1.54 MAXMF + .724 MAXSLOP - 5.16 MINWIND + .419
	Minimum slope (%)			
	Maximum wind speed (mph)			
	Maximum 1 hr fuel moisture (%)			
	Maximum slope (%)			
	Minimum wind speed (mph)			

APPENDIX E

Suggested Standardized Report Format

Figure 6. Prescribed Burn Reporting Format

I Location/Burn Unit Information

Agency	______	Field Unit	______
Location	T R S	Fiscal Year	______
Acres	______	Elevation	______
Slope	______	Aspect	______
Vegetation Type	______	Soil Type	______
Type of Burn	Underburn, Clearcut, Piles (circle one)	Burn Unit ID #	______
~~Projected Cost~~		Projected Cost	______

II Burn Objectives

	(Check)	Indicate Site Variables to be Measured to Assess Objective Accomplishment (See Section III)
Hazard Reduction	______	______
Silviculture	______	______
Wildlife Habitat Improvement	______	______
Range Management	______	______
Insect/Disease Control	______	______
Species Manipulation	______	______
Other (Specify)	______	______

State Objectives in Measurable Terms ______

III Monitoring For Fire Effects

Pre-Burn Date:		Post-Burn Date:	
A. Residue		**A. Residue**	
Natural ___ Activity ___ (Check One)			
Down Woody		Down Woody	
Ø-1/4"	______ T/A	Ø-1/4"	______ T/A
1/4-1"	______ T/A	1/4-1"	______ T/A
1-3"	______ T/A	1-3"	______ T/A
3"+	______ T/A	3"+	______ T/A
Total Loading	______ T/A	Total Loading	______ T/A
Duff Loading	______ T/A	Duff Loading	______ T/A
Duff Depth	______ IN	Duff Depth	______ IN
Fuel Depth	______ FT	Fuel Depth	______ FT
Dead/Live Ratio	______ %	Dead/Live Ratio	______ %

Pre-Burn Distribution:	Horizontal	Vertical	Post-Burn Distribution:	Horizontal	Vertical
Continuous	______	______	Continuous	______	______
Discontinous	______	______	Discontinous	______	______
	(Check One)			(Check One)	

Pre-Burn	Post-Burn
B. Live Trees Species: ______ Ø.1-1" ______ #/Acre 2-5" ______ #/Acre 6-1Ø" ______ #/Acre 1Ø"+ ______ #/Acre	B. Live Trees Species: ______ Ø.1-1" ______ #/Acre 2-5" ______ #/Acre 6-1Ø" ______ #/Acre 1Ø"+ ______ #/Acre
C. Shrubs Species: ______ Crown Cover ______ % Plants ______ #/Acre Availability ______ (H-M-L)	C. Shrubs Species: ______ Crown Cover ______ % Plants ______ #/Acre Availability ______ (H-M-L)
D. Herbaceous Vegetation Forbes ______ lbs/Acre Grass ______ lbs/Acre	D. Herbaceous Vegetation Forbes ______ lbs/Acre Grass ______ lbs/Acre
E. Snags <15" DBH ______ #/Acre 15"-3Ø" DBH ______ #/Acre 3Ø"+ DBH ______ #/Acre	E. Snags <15" DBH ______ #/Acre 15"-3Ø" DBH ______ #/Acre 3Ø"+ DBH ______ #/Acre
F. Nurse Logs ______ #/Acre	F. Nurse Logs ______ #/Acre
G. Mineral Soil Exposure ______ %	G. Mineral Soil Exposure ______ %
H. Plantable Sites ______ #/Acre	H. Plantable Sites ______ #/Acre
I. Insect/Disease Affected Trees ______ #/Acre	I. Insect/Disease Affected Trees ______ #/Acre

IV Fire Behavior

	Planned	Actual	Prescription Refinements for future burns
A. Effects (Inside Unit)			
NFFL Fuel Model			
Firing Pattern			
Strip Width			
Flame Length	FT	FT	FT
Rate of Spread	CH/HR	CH/HR	CH/HR
Fireline Intensity ($I=5.67\ F_L^{2.16}$)*	BTU/FT/SEC	BTU/FT/SEC	BTU/FT/SEC
Heat/Unit Area ($H_A=\frac{54.\overline{54}I}{R}$) **	BTU/FT^2	BTU/FT^2	BTU/FT^2
Residence Time ($\frac{0.9\overline{09}D}{R}$) ***	MIN	MIN	MIN
Scorch Height	FT	FT	FT
B. Control (Outside Unit)			
NFFL Fuel Model			
Rate of Spread	CH/HR	CH/HR	CH/HR
Fireline Intensity	BTU/FT/SEC	BTU/FT/SEC	BTU/FT/SEC

V Environmental Conditions

	Planned	Actual	Prescription Refinements for future burns
Temperature	°F	°F	°F
Relative Humidity	%	%	%
Midflame Windspeed	MPH	MPH	MPH
Wind Direction			
Shading	%	%	%
1 HR Fuel Moisture	%	%	%
1Ø HR Fuel Moisture	%	%	%
1ØØ HR Fuel Moisture	%	%	%
1ØØØ HR Fuel Moisture	%	%	%
Live Fuel Moisture	%	%	%
Duff Moisture	%	%	%
Soil Moisture	%	%	%

* I= Fireline Intensity, F_L= Actual Flame Length (Ft)

** H_A= Heat/Unit Area, I= Fireline Intensity, R= Rate of Spread (Ch/hr)

*** D= Flame Depth(ft), R= Rate of Spread (Ch/hr)

Please Note: EQUATIONS for Heat/Unit Area and residence time have been modified from standard equations in literature so that rate of spread can be entered in chains/hour rather than feet/minute. Most managers measure ROS in chains/hr.

VI

PRESCRIPTION FIRE RECORD

WINDSPEED = O
HUMIDITY = X
TEMPERATURE = ■
FUEL MOISTURE = ▲

LIMITS

PROJECT NAME UNIT DATE

90												
80												
70												
60												
50												
40												
30												
20												
10												
0												
TIME (2400 HR)												
FLAME LENGTH (FT)												
ROS (CH/HR)												
OTHER												

FORM 5150

... Evaluation

Date(s) of Burn ____________________
Time of Burn ____________________
Date Evaluated ____________________

Were objectives completely met? __________ (Yes/No)

If objectives were not completely met, specify why not: ____________________

Is there any evidence of tree damage or mortality due to insects or disease? ____________________ (Yes/No)

Did the fire burn out of prescription at any time? __________ (Yes/No)

Did crowning occur? __________ (Yes/No) Individual Extensive
(Circle one)

Was there any spotting? ______________ (Yes/No)

Did the fire burn outside pre-planned area? __________ (Yes/No)

How large was escape? NA <1/4 acre 1/4-1/2 acre 1/2-1 acre 1-1Ø acre >1Ø ac...
(Circle one)

Cost per acre for entire burn (including planning, monitoring, and evaluating):$

Did cost per acre exceed projected cost per acre? __________ (Yes/No)

If yes, why? ____________________

Did cost for burn exceed benefits gained? __________ (Yes/No)

If yes, why? ____________________

Is there any need for changes in prescription elements to better meet objectives? ____________________ (Yes/No)

If yes, specify needed changes: ____________________